QSO outflows and IXO

Mat Page
MSSL-UCL

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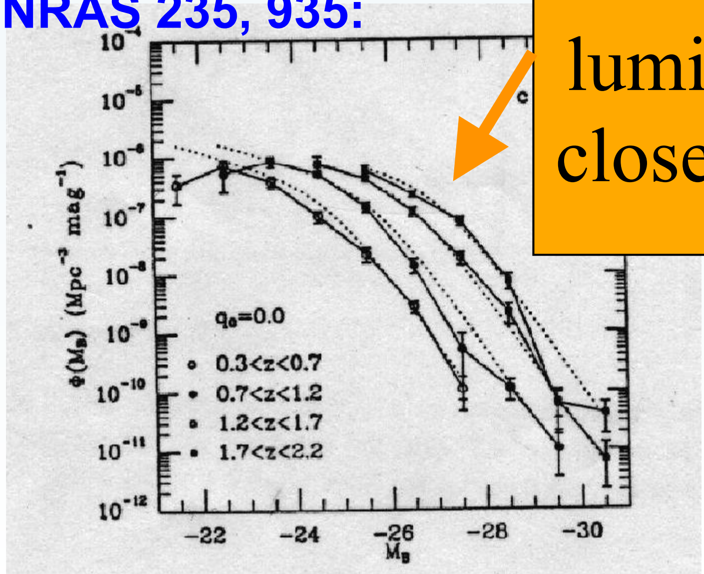
- Motivation: what role do QSOs play in galaxy formation?
- Which QSOs do we need to look at?
- Submm emission in QSOs
- Winds from QSOs
- What we need to look for with IXO
- Winds from nearby AGN: we need the physics as well.

QSOs and star formation at z~2

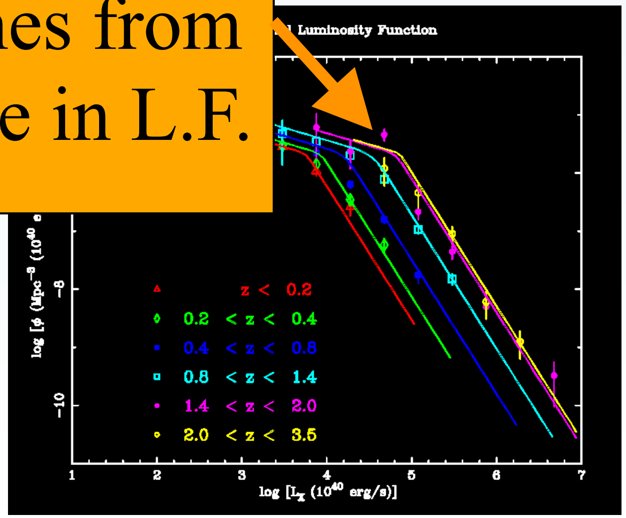
- The black hole/bulge mass relation tells us that the formation of spheroids and black holes are intimately linked.
- QSOs had their heyday at z~2.
  - Most vigorous period of black hole growth.
  - If black holes and stars grow together, QSOs should also be forming stars rapidly.
- Peak of star formation rate also at 1< z < 3.

Boyle et al. 1988, MNRAS 235, 935:



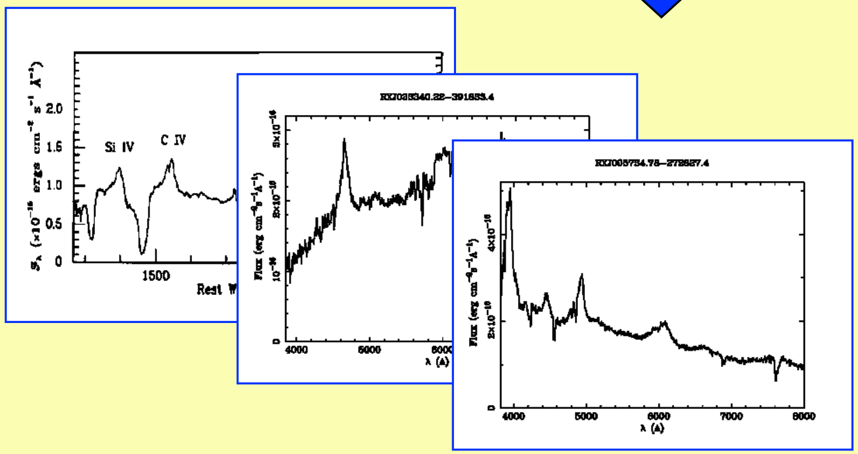
Most of the accretion luminosity comes from close to the knee in L.F.

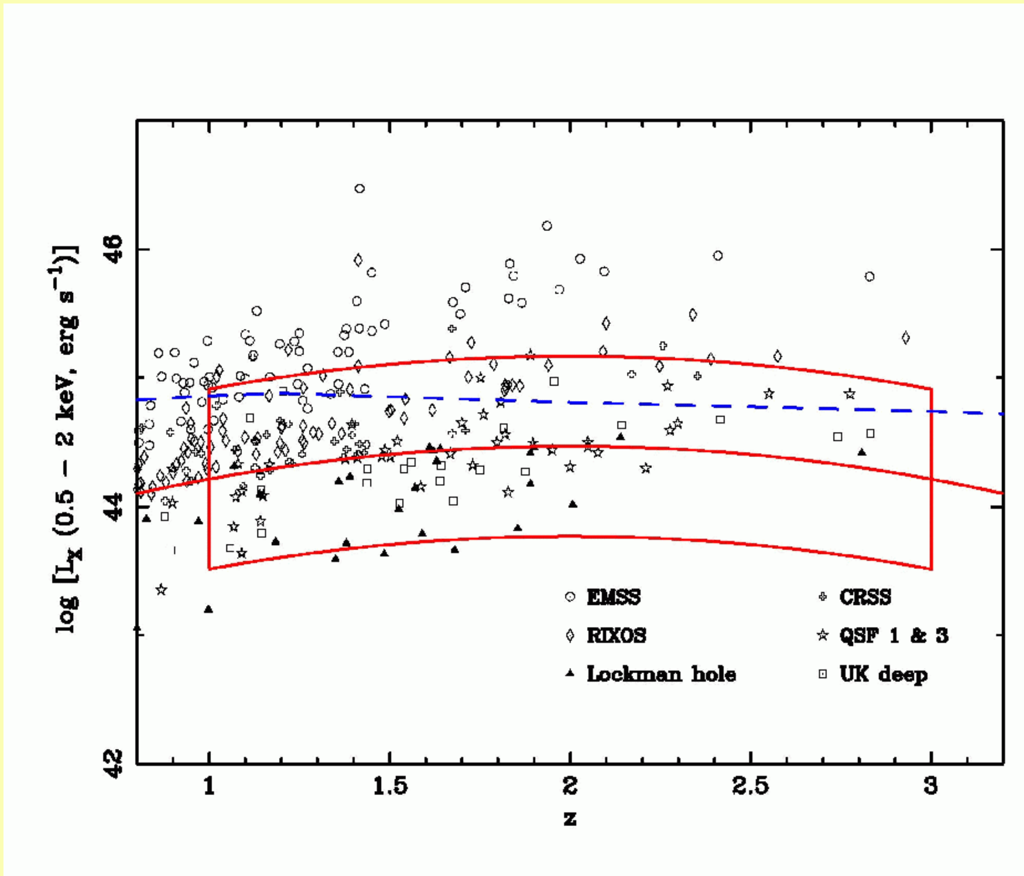
Page et al. 1997, MNRAS 291, 324:



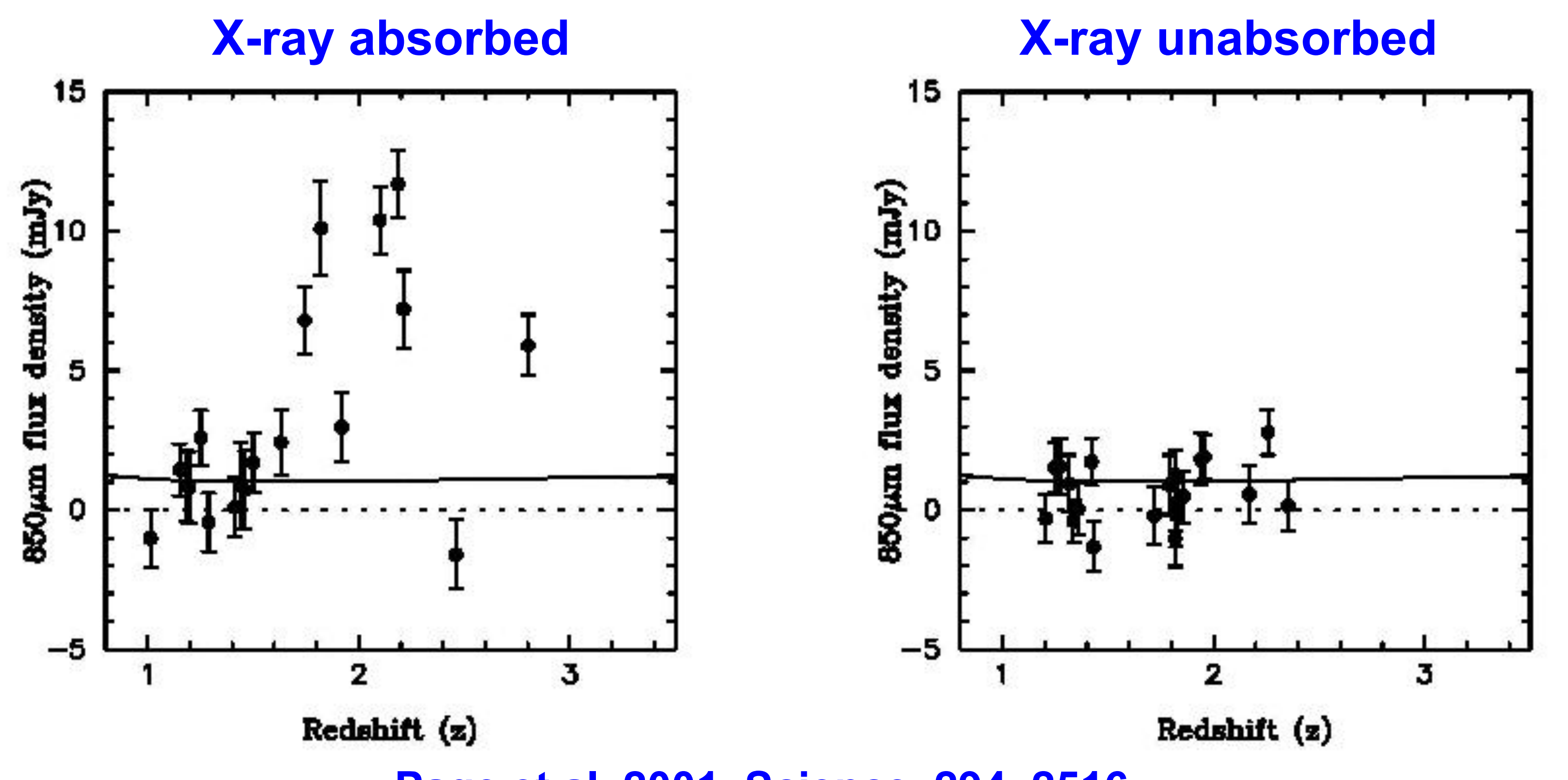
Hunt for star formation in QSOs using SCUBA / 850um

- **Drew samples of QSOs**
  - 1<z<3
  - close to L*
  - that we ought to be able to detect with SCUBA.
- **Two samples of QSOs:**
  - X-ray unabsorbed
  - X-ray absorbed





Here are the results:



Page et al. 2001, Science, 294, 2516
Page et al. 2004, ApJ, 611, L11
Stevens et al. 2005, MNRAS, 360, 610

X-ray absorbed and X-ray unabsorbed QSOs are completely different in submm, i.e. star formation.

What does this mean?

- X-ray absorbed QSOs are ULIRGs/hyperLIRGs
  - **The objects have L_{FIR} between 1 and 4 times L_{AGN} – must be star powered.**
  - **Can't be to do with orientation.**
- Therefore they probably form part of an evolutionary sequence.
  - **Bulge not finished yet - earlier than typical QSOs.**
  - **Black holes already large - must be later than typical submillimetre galaxies.**
  - **Only about 10% as numerous as normal QSOs.**

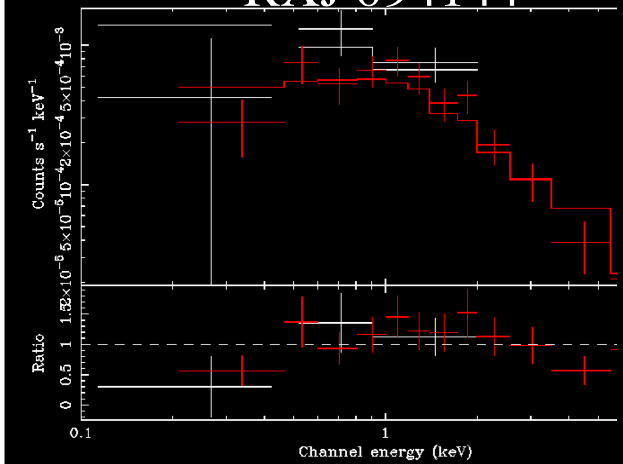
X-ray absorbed QSOs are a brief transition stage between the ultraluminous starburst and the unobscured QSO phase.

XMM-Newton spectra

UCL

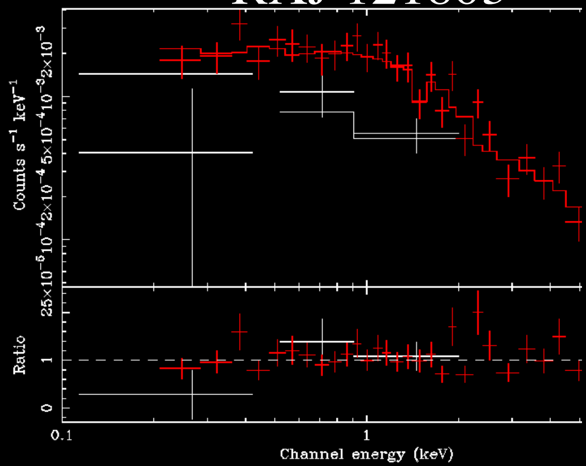
What is the absorption? cold gas or ionised gas?

RXJ 094144



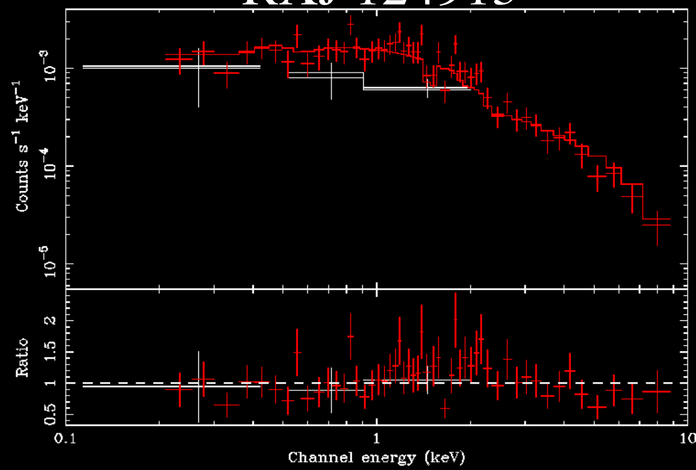
Γ=1.3 +/- 0.1

RXJ 121803



Γ=1.4 +/- 0.1

RXJ 124913



Γ=1.4 +/- 0.1

- **Cold absorbers:**
  - χ^2/υ is OK, but funny residuals, abnormal distribution of Γ
  - Underlying spectra <u>would not be normal</u> for QSOs!
- **Ionised absorbers:**
  - Reasonable fits, reasonable Γ, no funny residuals.

Page et al, MNRAS, in submission

Tells us: The absorbers are probably ionized
We need much better X-ray spectra

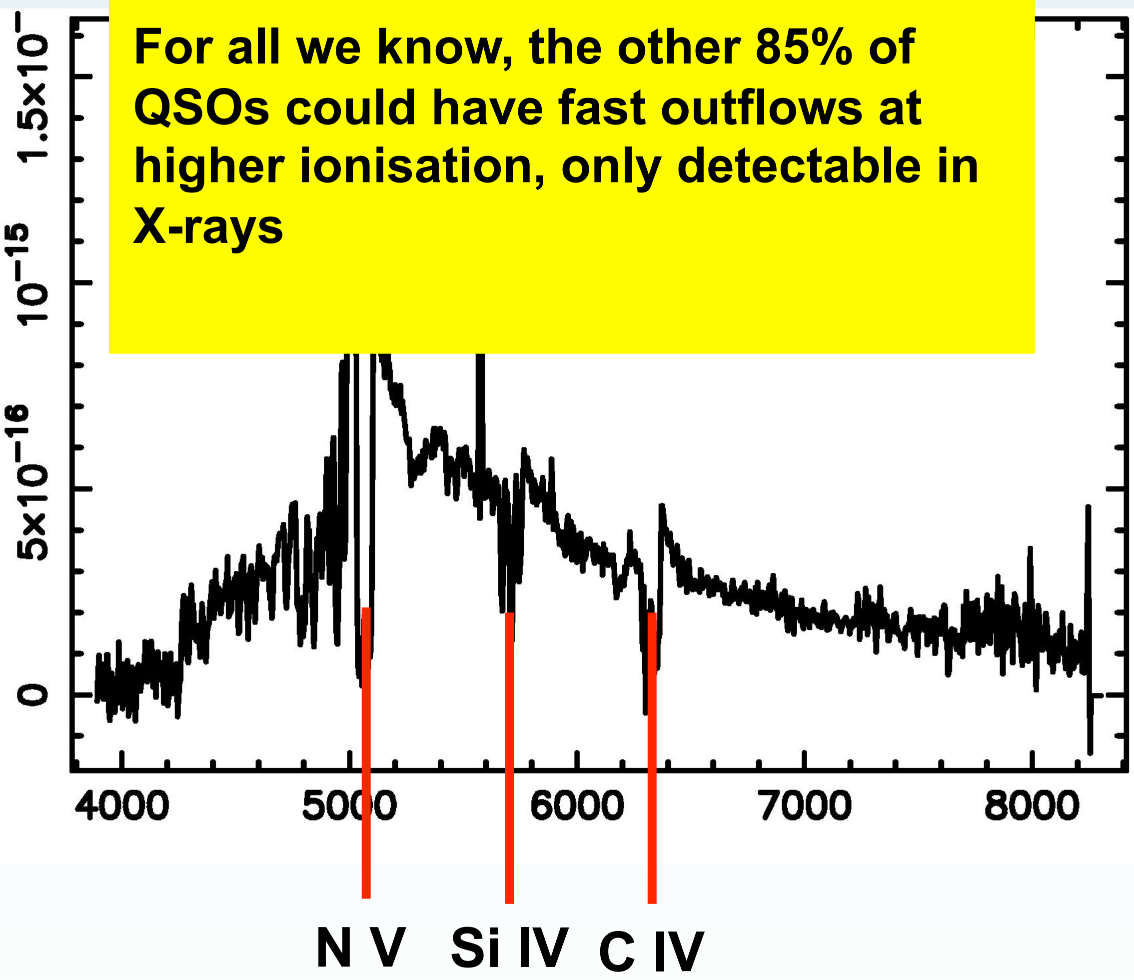
Ionised winds and QSOs

- **RGS on XMM-Newton has told us:**
  - AGN ionised absorbers are almost always winds.
  - They contain little dust - probably sublimated as it joins outflow.
  - Most of the absorbing gas seen only in the X-ray.
  - Even the weedy Seyferts of today can have large mass outflow rates $M_{out} > M_{acc}$.
- **QSOs with ionised winds are rapidly forming stars.**
- **The winds are probably scaled up versions of Seyfert winds.**
- **Winds look to be very important in the evolutionary connection between AGN and galaxy formation.**

These winds can eject a lot of material, so could they be fundamental to QSO evolution in general?

Completely different angle on importance of ionized winds in QSOs:

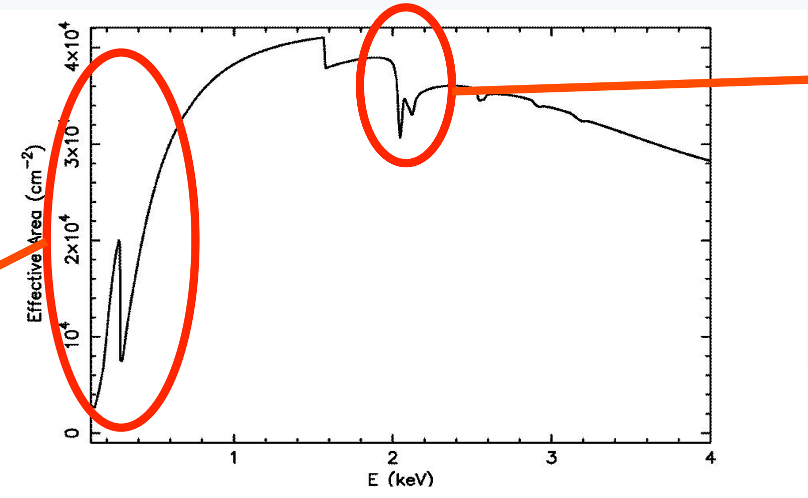
- UV BALs in 15% of QSOs
- Extremely faint in X-rays: heavily absorbed
- CIV 6x more common than MgII
- Higher ionisation lines only visible in X-rays
- Huge discovery potential for IXO



We won't find out what ionized winds do in QSOs until IXO.

- Take a "typical" QSO, simulate an IXO spectrum with a toy model.
- z=2, L=$10^{44.5}$ (0.5-2 keV), Galactic column of 2 x 10^{20} cm^{-2}
- Add absorption lines from OVII, Fe
- Assume saturated lines with FWHM = 3000 km/s
- Include Fe UTA and 6.9 keV lines at similar to those in NGC3783.
- Illustrative only - no edges, very few abs lines, no emission lines, power law continuum.
- Guilty confession*: simulated with TES response matrix from an ESA/ JAXA mission beginning with X, 100ks exposure

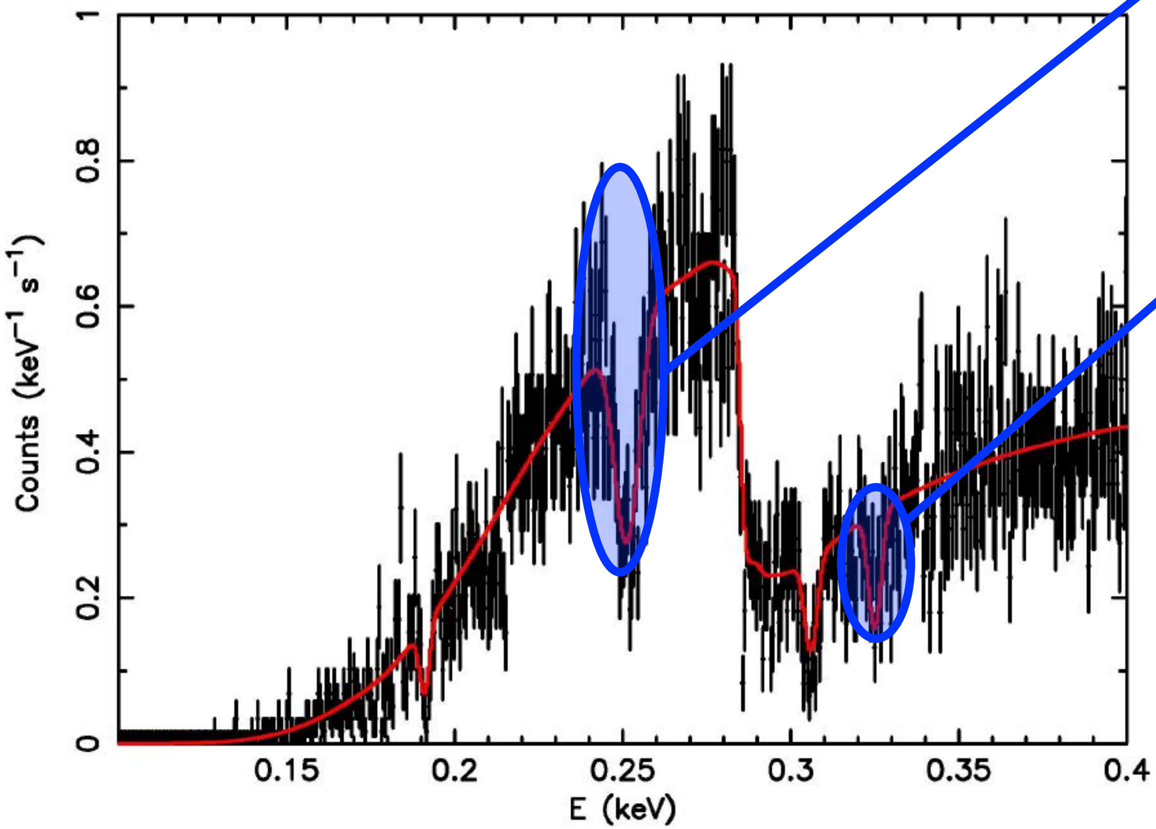
Soft X-ray lines here



Fe K lines here

*** But you'll get the point.**

The results:

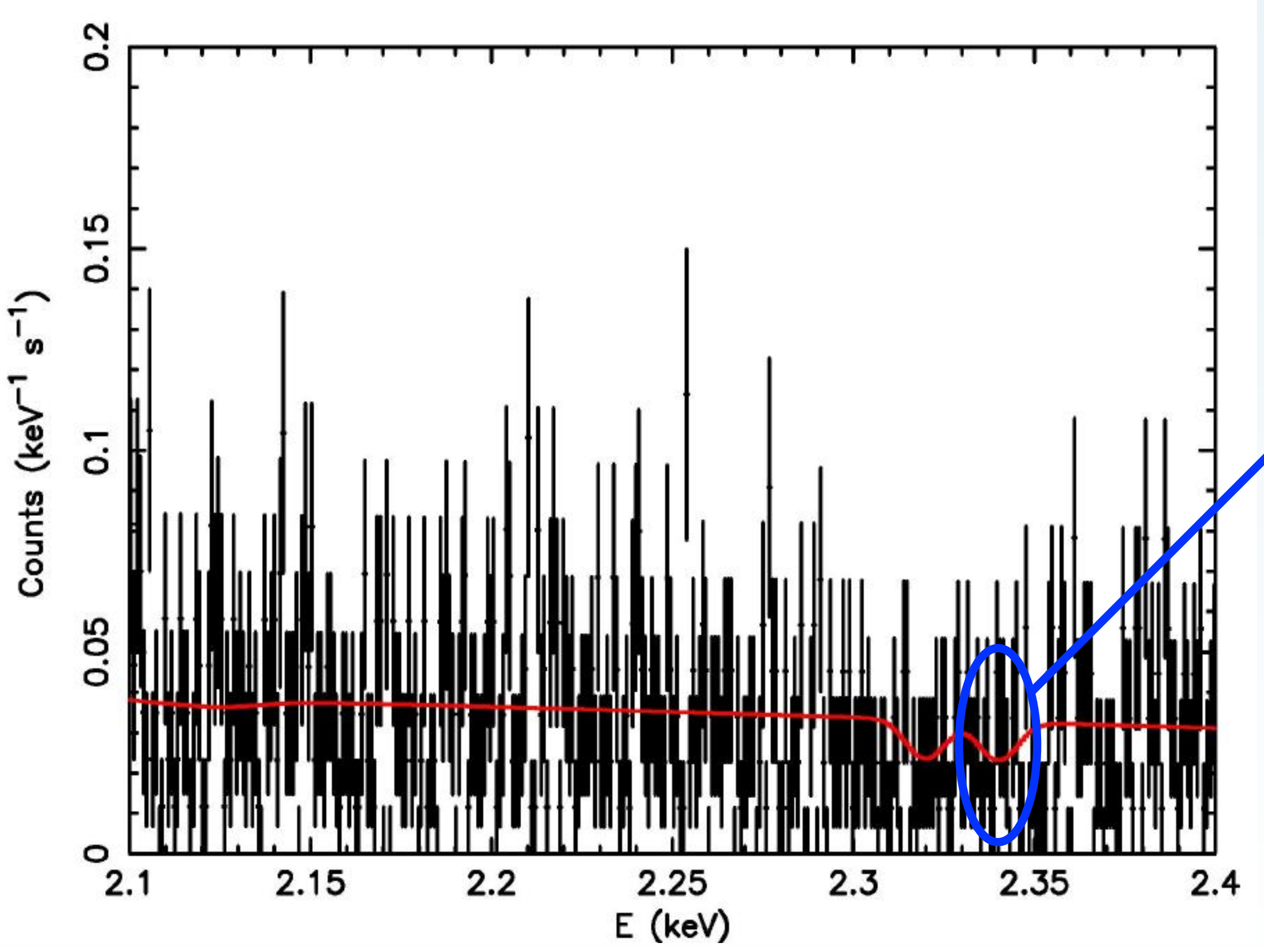


Fe UTA is easy

Other lines possible if broad

We can get the dynamics, column densities, outflow rates, abundances, etc for QSO outflows!

What about the Fe K lines?:



Fe K absorption lines almost impossible

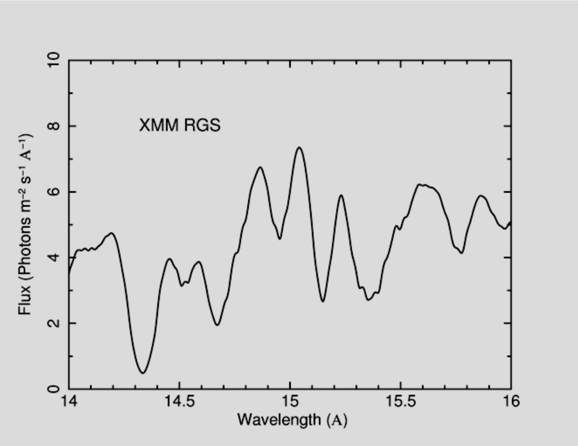
We really need the low energy response on IXO!

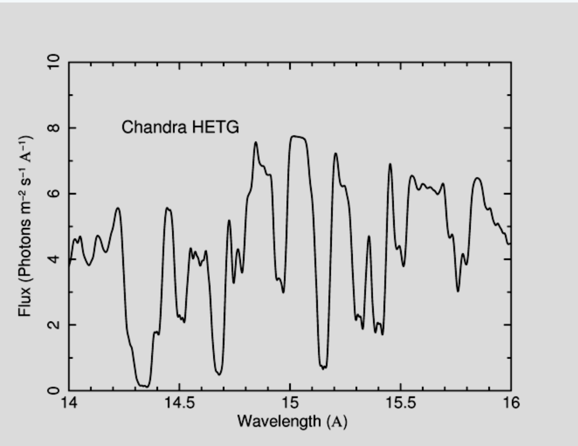
BUT!
We also need something else to understand ionized outflows in QSOs.

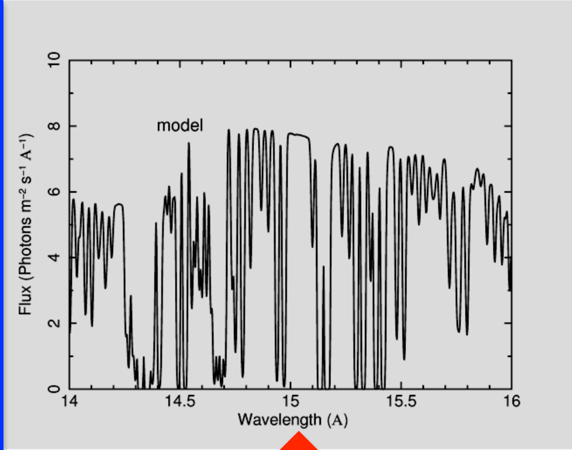
- **We need to understand the physics of AGN outflows in bright, nearby AGN before we can apply it to our z=2 observations.**
- **Fantastic advances in the last 10 years, but our understanding is still terribly limited.**
- **Fundamental problem is that we have never had X-ray spectra with high enough resolution.**

The best studied AGN warm absorber: NGC3783

Today's resolution



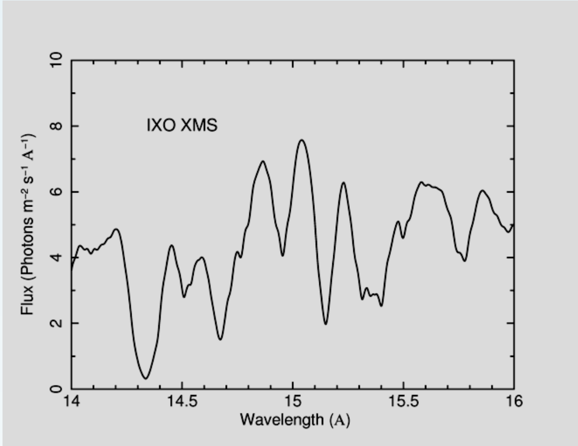


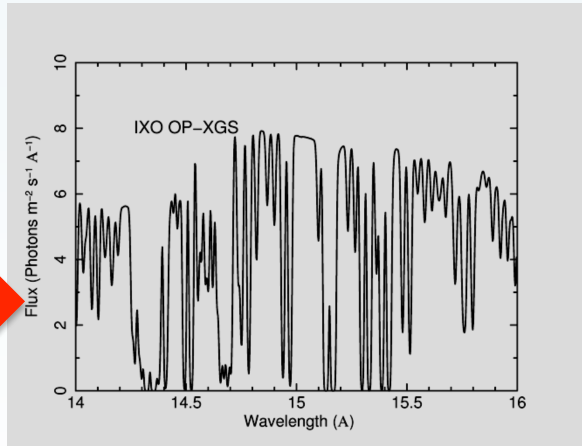


This is our current estimate of what the spectrum actually looks like.

Only the IXO XGS tells us what the spectrum actually does look like.

Tomorrow's resolution





- Today, we don’t resolve the X-ray absorption line profiles in <u>any</u> AGN with <u>any</u> instrument.
  - We don’t know if the X-ray source is fully covered.
  - We don’t know what the velocity dispersions of the outflows are, or whether they consist of multiple components.
  - We don’t know where they come from.
  - We can’t be certain how much mass or energy is carried in the outflows.
  - We don’t know how they are driven.
  - We don’t know what they do to the AGN or to the surrounding galaxy.
- We need to resolve the absorption lines to answer all these fundamental questions.

Conclusions

- **X-ray absorbed QSOs at z=2 have ionized winds, and are hosted by ultraluminous galaxies with huge star formation rates.**
- **The absorbed QSOs appear to represent a transitional phase between submillimetre galaxies and QSOs.**
- **These winds <u>could be</u> the terminators of star formation <u>and</u> accretion.**
- **Incidence of UV broad absorption lines as a function of ionization <u>also</u> shows that highly ionized X-ray absorbing winds could be very important in the evolution of QSOs.**
- **Huge discovery space for IXO in understanding the role of winds in QSO evolution.**
- **The IXO grating spectrometer is <u>fundamental</u> to show us how AGN winds work.**
- **Soft X-ray response of cryogenic spectrometer is <u>very</u> important to tell us about z~2, the epoch of galaxy formation.**